946

NEW TYPES
OF
FOREIGN MOTORS

PREPARED IN THE OFFICE OF
THE DIRECTOR OF AIR SERVICE

AUGUST, 1919

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

WAR DEPARTMENT

Document No. 946

Office of The Adjutant General

WAR DEPARTMENT,
WASHINGTON, *August 4, 1919.*

The following publication, entitled "New Types of Foreign Motors," is published for the information and guidance of all concerned.

[062.11, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
General, Chief of Staff.

OFFICIAL:

P. C. HARRIS,
The Adjutant General.

CONTENTS.

NEW TYPES OF FOREIGN MOTORS.

	Page.
1. The Benz motor (German)	9
2. The Mercedes aviation motor (German)	11
Cylinders	11
Piston and connection rods	12
The crank shaft and its mounting	12
The operation of accessories and distribution	13
Lubrication	14
Exhaust collector	14
Carburetor	14
Ignition	15
Radiator	15
200-horsepower Mercedes motor	15
Weight of Mercedes motor	15
3. The 450-horsepower Napier "Lion" (British)	16
The self-starting device	16
Lubrication	17
Ignition	17
The crank case	17
Cylinders	18
Pistons	18
Connecting rods	18
Crank shaft	18
Water pump	18
4. The Rolls-Royce motor—The "Eagle" (British)	19
Type	20
Number of cylinders	20
Firing order	20
Bore	20
Stroke	20
Displacement	20
Compression ratio	20
Normal speed	20
Normal horsepower	20
Guaranteed life at normal speed	20
Normal fuel and oil consumption	21
Encombrement	21
Weight, dry, in pounds	21
Valving and valve gear	21

4. The Rolls-Royce motor—The "Eagle"—Continued. Page.
Timing 21
Valve spring 21
Valves 21
Piston 21
Connecting rods 22
Wrist pins 22
Crank shaft 22
Cylinders 22
Cooling system 22
Oil system 22
Air-pressure pump 22
Carburetion 22
Clearances 23
Spring drive 23
Reduction gears 23
5. The Salmson engine—Type 9Zm (French) 23
Introduction 23
Technical description 24
Engine 24
Crank case 25
Cylinders 25
Pistons 25
Connecting rod 26
Crank shaft 26
Bearings 26
Distribution 26
Lubrication 27
Water circulation 28
Tachometer 28
Ignition 28
Carburetor—"Zenith" 30
Operation 30
Altitude corrector 31
Adjustment of carburetor 31
Adjustment of distribution 31
Adjustment of ignition magneto 32
Dismantling of engine 33
Assembling 34
Valve grinding 34
Preparing and starting engine 34
Starting with starting carburetor 35
Management of engine 35
Difficulty in starting 36
Lack of tightness 37
Misfire 37
Poor carburetion 37
Miscellaneous 38
6. Siemens-Halske rotary engine (German) 39

Page.
7. The Fiat motor (Italian) 40
General principles 40
Cylinders 40
Valve guides 40
Timing the valves 41
Pistons and connecting rods 41
The cam shaft 41
Upper and lower crank case 41
Carburetor 42
Ignition 42
Lubrication 42
8. The 300-horsepower Maybach aero engine (German) 43

NEW TYPES OF FOREIGN MOTORS.

1. THE BENZ MOTOR (GERMAN).

Following the usual German aero motor practice, the 230 horsepower Benz engine is of the six-cylinder, vertical, water-cooled type. Each separate cylinder is bolted to the crank case by long bolts and studs, which pass through the crank chamber top half and secure the crank-shaft bearings between the top and bottom halves of the crank chamber. Two inlet and two exhaust valves are fitted in the head of each cylinder. The pistons are of cast iron, fitted with three exceptionally wide rings, and the piston heads, following the usual Benz practice, are supported by conical steel forgings riveted and welded to the piston crown, which bear on the center portion of the gudgeon pins through slots cut in the connection rod small ends. The lubrication of the crank shaft and connecting-rod bearings is effected by a very neatly designed gear pump working in an auxiliary oil reservoir formed in the bottom of the air-cooled base chamber. An oil-sealed petrol pump of interesting design supplies petrol to the carburetors in conjunction with a supplementary pressure reservoir inclosed in the main petrol tank.

Except for the steel water jackets, the cylinders are made entirely of cast iron. The bore of the cylinders is 144 mm. and the thickness of the cylinder walls tapers from 5.5 mm. at the base flanges to 6.5 mm. at the top of the cylinder barrels. The water spaces formed in the cylinder heads and the cooling of the valve pockets are well carried out. Dished plates are welded in position in the water space above the crown of each cylinder to deflect the flow of water on to the exhaust-valve pockets. The total weight of each cylinder complete with valves, valve, springs, and valve rocker supports equals 44.25 pounds.

The pistons, with exception of the small conical pillars, are made entirely of cast iron and weigh 7.62 pounds each, complete with rings and gudgeon pins. Three rings are provided above the gudgeon pin, the lower one being a scraper ring. The gudgeon pins are 39 mm. in diameter and are bored 30 mm. inside diameter. The very clean design of the tubular connecting rods is apparent in the photo-

graphic views. The six-throw crank shaft runs on seven plain bearings, and weighs 109.25 pounds, including the propeller boss. The cranks are, of course, set at 120°, and the diameter of all the journals is 62 mm., while that of the crank pins is 60 mm.

The hollow cam shafts each run in three plain phosphor-bronze bearings, and are arranged inside the top half of the crank chamber. The method of cooling the interior of the crank chamber and sump indicates the fact that this matter has received most careful consideration in design.

At the top half of the crank case six of the seven main bearing houses are cast so that the webs form air passages transversely across the engine. The bottom half of the crank chamber is extended to form an oil sump and is of unusual design. Breathers are also fitted into the top half of the crank chamber.

Two separate carburetors are fitted, each feeding three cylinders. At full throttle most of the air is taken through the air ports in the throttle above the jets. When the throttle is closed for slow running the main jet is completely cut off and all the air is taken through the passage containing the pilot jet. The slow running of the engines is very good. No compensating arrangement is fitted for high altitude control. The R. A. F. test report computes the petrol consumption at 150 pints per hour, equaling 0.65 per brake horsepower hour. The connections between the flanged bends of the induction pipes and the cylinders, and also between the bottom ends of the induction pipes and the carburetors, are made with rubber ring joints secured by wide band clips.

The crank-shaft journals and crank pins are bored for lubrication, the webs being drilled with communicating holes in the usual manner. A double-thrust ball race, 120 mm. in diameter, is fitted at the front end of the crank shaft behind the front flange, to which the propeller hub is bolted. Fitted to the rear end of the crank shaft is a friction clutch for operating the wireless drive, which is designed so that the driving brake shoes of the clutch can be thrown in or out of engagement with the driving pulley from the pilot's seat through the action of two wedges which operate the friction shoes through the ball-ended levers.

The twin inlet and exhaust valves work vertically in the cylinder heads, and are operated by rockers mounted on ball bearings, carried by supports screwed into the cylinder head. The dimensions of both the inlet and exhaust valves are the same, each valve weighing 1.25 pounds. The lift of the inlet valves equals 0.465 inch, and lift

of the exhaust valve equals 0.0443 inch. Clearance of inlet tappet equals 0.009 inch, exhaust 0.015 inch.

2. MERCEDES AVIATION MOTOR (GERMAN).

This motor is one of the five types standardized by the German War Office and is in very general use at the present time. Its maximum power is 176 horsepower at 1,450 revolutions per minute. This motor is of the fixed vertical type, has six cylinders in line, which are not offset, and is water cooled. The cam shaft is carried in a special bronze case, seated on the immediate top of the cylinders, which in turn is driven by bevel gearing, a vertical shaft being interposed between the crank shaft and cam shaft.

The water pump is located on this vertical shaft and serves to steady the motion of this shaft. Extending immediately below the cam shaft is another vertical shaft, driven by bevel gears off from the crank-shaft master bevel, terminating in a worm, which drives the multiple piston oil pumps.

Cylinders.

The cylinders are made from steel forgings, as are the valve chamber elbows, which are machined all over and are welded together. A jacket of light steel is welded over the valve elbows and attached to a flange on the cylinder, allowing for a water-cooling space, having a section of about 10 mm., or seven-sixteenths of an inch. The bore of the cylinders is 140 mm., or $5\frac{1}{2}$ inches; the stroke is 160 mm., or $6\frac{5}{16}$ inches.

The volume of the compression chamber is 0.645 liter, the cylinder capacity being 2 liters 0.463. The ratio volume is 4.818. The cylinders are locked to the crank case by means of dogs and long through bolts, which have shoulders near their lower ends and are bolted to the lower half of the crank chamber. All this gives an exceedingly stiff and light structure, and the construction has been imitated by a great many other builders.

There are a number of peculiarities in connection with these cylinders which are well worth noting. In plate 3, which is a longitudinal section through the motor, the water-cooling system will be clearly apparent. The water after leaving the water pump enters the top of the front cylinders and passes successively through each of the six cylinders. There are short tubes welded to the top of the water jackets which serve as a communicating gallery. This same system of cooling was used for years by the Panhard Co., of Paris, on their motor-car engines. It has more recently been used in

connection with the English White and Poppe motor-truck engines. Excellent circulation is had around the valve chambers and cylinder heads.

It will also be noted that a lug has been forged with the valve elbow, which serves as the anchor and steadiment for the cam-shaft housing.

Piston and Connection Rods.

The pistons are built up of two pieces. First, a dropped forged steel head, extending from which are the piston pin bosses, and secondly, a cast-iron skirt, into which this head is screwed. The skirt carries three rings at its upper end and one on its lower end. There are also a couple of lubricating oil grooves cut into this skirt.

After the head has been screwed into the skirt, it is retained by two small rivets and is welded at a couple of points. The coefficient of friction between cast iron and steel is considerably lower than between two steel members, and there is less tendency for a cast-iron piston to cut or score than where a steel piston is used. A great many makers have tried steel pistons and afterwards given them up and gone over to cast iron. For instance, in the original Gnome engines, steel pistons with a single brass ring were used. These were afterwards given up, and in all the Gnome engines now being built cast-iron pistons, with a percentage of steel in the mixture, are the invariable standard. The Le Rhone rotating engine, which has necessarily steel cylinders, has a cast-iron liner forced into these cylinders for wearing surface.

There are also some distinct advantages possessed by this piston design. The skirt can be readily machined all over, and may have uniform wall thickness, which in itself greatly assists in preventing distortion. The piston pin is formed from a chrome nickel steel tube and is retained in the piston by means of a simple set screw and cotter pin.

The connecting rods are very short and very stiff of I-beam section and are machined all over. At their upper end there is a floating bronze bush, which bears on the piston pin. Banded to the web of the rod is an oil tube for conveying lubricant from the crank pin to the piston pin.

The Crank Shaft and Its Mounting.

The crank shaft is also a chrome nickel steel member and is carried on seven bearings. There are holes through each of the crank-pins and main bearings fully half the diameter of the shaft, which are plugged by pressed brass members. Small holes are drilled through

the crank cheeks, which serve to convey lubricant from the main bearings to the crank pins. The propeller thrust is taken by a simple ball thrust bearing at the propeller end of the crank shaft. This thrust bearing is seated in a steel retainer, which is clamped between the two halves of the crank case. At the forward end of the crank shaft there is mounted a master bevel gear on six splines. This bevel floats on the splines against a ball-thrust bearing, and in turn this thrust is taken by the crank-case cover. A stuffing box prevents the loss of lubricant out of the front of the crank chamber, and an oil-thrower ring serves the same purpose at the propeller end of the crank chamber.

The Operation of Accessories and Distribution.

With a motor speed of 1,450 revolutions per minute, the vertical shaft at the forward end of the motor turns 2,175 revolutions per minute. This is also the speed of the two magnetos and the water pump. The lower vertical shaft bevel gear and the magneto driving gear are both made integral with the vertical driving shaft, which in turn are carried in plain bearings in an aluminum housing. This housing is clamped by means of three studs to the upper half of the crank case.

The cam shaft carries 18 integral cams, the inlet and exhaust cams, as well as a set of half compression cams, which are formed with the exhaust cams and which are put into action by means of a lever at the forward end of the cam shaft. The cam-shaft bevel gear is fastened to the cam shaft by means of multiple splines. Shaft is hollow, and serves as an oil galley for conveying lubricant to each of the cam-shaft bearings. At the forward end of the cam shaft there is also mounted an air pump for maintaining pressure on the fuel-supply tank and a bevel gear tachometer drive. The timing is as follows:

Opening of the inlet valves.—2½ mm. after the top dead center on the piston stroke, or 14° of crank-shaft motion.

Closing inlet valves.—15 mm. on the up stroke of a piston, or 36° of crankshaft motion past the bottom dead center.

Opening the exhaust valves.—24 mm. before the bottom dead center, corresponding to 46° of crank-shaft motion.

Closing exhaust.—½ mm. after the top dead center for 4° of crank-shaft motion.

Lubrication.

Lubrication is, of course, carried out by a full-pressure system. The oil is pumped through a single manifold, with seven branches to the crank-shaft main bearings. Then in turn through the hollow crank shaft to the connecting rod big ends and thence through small tubes to the piston pins.

The oil pump has four pistons and two double valves driven from a single eccentric shaft, on which is mounted four eccentrics. The pump is continually submerged in oil. One of the large pumps draws oil off from the base and the other one pumps filtered oil to the bearings. In order to avoid great variations in pressure in the oil lines, there is a piston-operated pressure regulator cut in between the pump and the oil lines. The two small pistons take fresh oil from a tank located in the fuselage of the machine. One of these pumps delivers oil to the cam shaft and the other delivers oil to the crank shaft; this fresh oil mixes with the used oil and returns to the base and back to the main large oil pump cylinders. By means of these small pumps a constant quantity of oil is kept in the motor, and the oil is continually refreshed by means of the new oil coming in. All of the oil pipes are fastened into the lower half of the crank chamber very securely.

There is also some cooling of the oil affected by air passing through cast channels in the crank case on its way to the carburetor.

Exhaust Collector.

A light steel manifold serves to connect the exhaust ports of each of the cylinders to central stack, which is inclined about 15° from vertical, and is arranged to exhaust just over the top of the upper wing of the plane.

Carburetor.

On the left side of the motor two tubular manifolds, each in the form of a T, connect the cylinder inlet ports with the double carburetor. The composition of the mixtures is maintained normal by means of an automatic air valve surrounding the throat of the carburetor, and without springs. A small primary nozzle is arranged to take care of starting and idling conditions. The air for the mixture is supposed to have been heated by passing through the cast channels in the crank chamber, and while the small amount of heat thus added to the air might assist in the carburetion of very light fuels, it is quite probable that considerably more heat would be required with American gasoline. The carburetor body itself is water jacketed.

Ignition.

The ignition is furnished by two Bosch Z–H–6 magnetos, which operate at a speed of 2,175 turns when the motor is up to normal speed. The maximum advanced position for the ignition is 12 mm., or 32° before the top dead center. Bosch plugs with steatite insulators are used. The firing order is 1, 5, 3, 6, 2, 4.

Radiator.

There is also included with this motor a radiator, which, together with the water jackets, has a capacity of 25 liters of water. This radiator is rectangular in shape and is normally tilted at an angle of 30° from vertical. The tubes are 125 mm. long. With the radiator it is 835 mm., and it is 186 mm. high. In this form it presents but a small amount of head resistance. Its weight is 26 kilograms.

200 Horsepower Mercedes Motor.

In addition to the motor just described, there is another motor with the same size cylinders, which, however, has eight cylinders and employs speed reduction gear, so that the propeller only turns at 900 revolutions per minute. This type of motor has been used extensively in the L. V. G. battle planes.

Weight of Mercedes motor.

	Kg.
Crank shaft, complete	34. 8
Lower half of crank case	39. 97
Upper half of crank case	31. 0
Six cylinders, complete	61. 24
Six connecting rods, complete	13. 86
Six pistons, complete	18. 7
Cam shaft, complete	21. 1
Carburetor	6. 6
Water pump with shaft and housing	6. 6
Oil pump with shaft	5. 85
Two operating magnetos	13. 0
One starting magneto	4. 0
Inlet pipe and ignition wire casing	11. 0
Miscellaneous parts	5. 5
Total	273. 22
Exhaust pipe, complete	7. 5
Radiator, empty	26. 0
Total	306. 72

3. THE 450-HORSEPOWER NAPIER "LION" (BRITISH).

The all-British "Lion" aero engine has many points of interest. The most noticeable novelty in the latest model is the new type of water jacket. There is now a separate jacket to each cylinder instead of a multiple jacket for each block of four cylinders. Undoubtedly, this is an improvement. Weight is saved, and the new method of making a water-tight joint between the cylinder and jacket is preferable to the old. In the former models the lower joint was made by a rubber ring; in the latest type the jackets are welded to the cylinders.

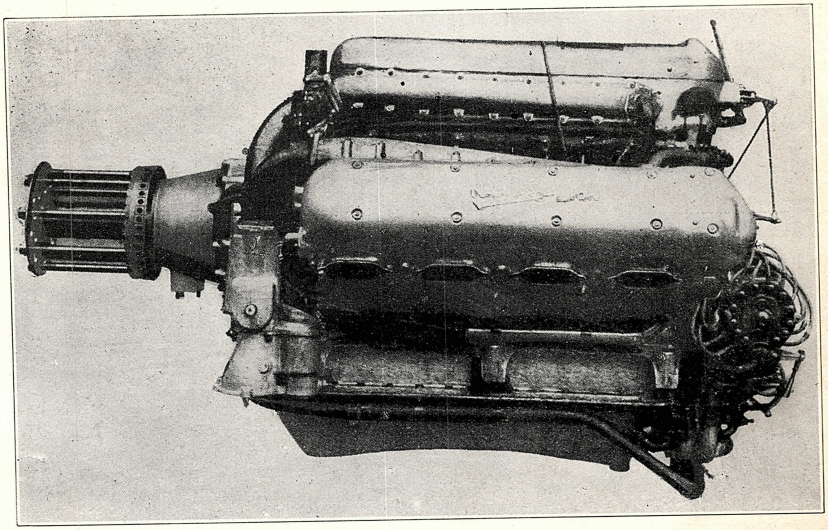
The "Lion" engine, which develops 450 British horsepower at 2,000 revolutions per minute and weighs only 1.86 pounds per British horsepower (without water, fuel, or oil), is in its entirety a highly creditable British production. Its 12 cylinders are arranged in three sets in the "broad arrow" method. Each cylinder has two inlet and two exhaust valves, the seatings of which are screwed through the head of the cylinder into the head casting. The valves are operated by two overhead cam shafts, and the cams act directly upon the tappet heads, the stems of which are screwed into the valve stems so that the clearance may be adjusted. A spring locking ring secures the tappet head when the adjustment has been made.

The Self-Starting Device.

The engine is started by pumping an explosive mixture into the cylinders and firing it by means of a hand-starting magneto. By means of linked control levers the two forward valves of each cylinder are opened by hand pressure. The air-pump is mounted in the cockpit, and by means of a two-way cock it can be used first to pump pure air to the cylinders to expel any foul gasses that there may be in the combustion chambers, and then the explosive mixture is ready for firing. The mixture is formed by pumping air through a petrol vaporizer which is a form of spray carburetor.

The three rows of cylinders are supplied with mixture, when running, by two carburetors—a single and a duplex type. The gas passages are water jacketed. So far as the throttles, diffusion jets, and altitude control cocks are concerned, the carburetors resemble the H. C. 7 type, but modifications have been made to adapt them to the "Lion" engine.

The altitude control system is that of reducing the supply of petrol as the machine climbs. This is, of course, necessary, because as the air becomes rarefied the percentage of air to petrol would become



THE NAPIER "LION" 450 HORSEPOWER AERO ENGINE. THIS POWER PLANT WAS USED BY CAPT. LANG IN ESTABLISHING THE WORLD'S ALTITUDE RECORD OF 30,500 FEET.

incorrect if the flow of fuel were not checked. There is a safety device, which causes the control when open to shut automatically when the throttle is closed. This prevents the mixture being too weak when the pilot makes a long dive and flattens out.

Lubrication.

Oil pumps of the spur-wheel type are fitted and the lubricant is fed under pressure to both ends of the crank shaft and from thence along the inside of the shaft to the crank pins and to the big ends and gudgeon pins. Oil is also supplied under pressure to one of the cam shafts on each set of cylinders and to the reduction gears. The cylinders are lubricated by oil splashed from the connecting-rod, big-end bearings and gudgeon. Two scraper rings are fitted to each piston and the oil from the upper scraper ring is drained through holes cut in the piston.

Ignition.

Two 12-cylinder magnetos are fitted. Both rotate anticlockwise and one has a special distributor rotor for starting purposes. They are driven at one-and-a-half times the speed of the crank shaft in order to give six sparks for each revolution of the engine, as this type of magneto gives four sparks to each revolution. Two plugs are, of course, fitted to each cylinder.

The Crank Case.

The crank case of the "Lion" is a fine casting of aluminium alloy. The top halves of the crank-shaft plain and roller bearings are contained in the two ends and four internal cross webs. The lower halves of the housings for the roller bearings are steel caps carried in studs in the rear and cross webs.

The casing for the reduction gear is formed at the front end of the crank case. It will be seen that the arrangement is extremely neat. There are six cam shafts—two for each set of cylinders, one operating the exhaust and one the inlet valves. Only one cam shaft on each set of cylinders is driven by the reduction gear; the other cam shaft is geared to this. Consequently, there are three shafts driven by the bevel gear wheel attached to the crank shaft. One shaft has two bevel wheels, one of which engages with the bevel wheel that drives the center shaft. The compact arrangement by which the six cam shafts, water pumps, oil pumps, and two magnetos are driven is clearly shown.

The following general particulars and dimensions are of interest:

Cylinders.

Steel forgings machined all over. Water jackets of steel. Detachable aluminium cylinder head, containing inlet and exhaust passages, valves and valve actuating mechanism.

Pistons.

Of aluminium alloy, fitted with two gas and two scraper rings. Gudgeon pins of large diameter and hollow, working in steel bushes.

Connecting Rods.

Machined from special high-grade steel. The master rod, coupled to the pistons of the vertical block of cylinders, is formed with lugs on either side, to which are attached the short auxiliary rods for the pistons of the right and left groups of cylinders. The big ends are white metal lined; anchor pins and other parts work in bushes of ample size.

Crank Shaft.

Machined from a solid steel forging. The four throws are in one plane, and all journal bearings and crank pins are of large diameter and bored out. The shaft is carried in five substantial roller bearings and a large plain bearing at the forward end.

Water Pump.

Centrifugal type, mounted to rear end of engine and running at half crank-shaft speed. The spindle is fitted with a metallic packed gland and a screw-down greaser. Water is delivered through a separate outlet to each of the three cylinder blocks.

Number of cylinders	12.
Arrangement	3 sets of four each, one vertical, two at 60°.
Bore	5½ inches.
Stroke	5½ inches.
Horsepower, normal	450 at 1,925 revolutions.
Direction of rotation of propeller shaft	Clockwise view from propeller end.
Speed of rotation of propeller shaft	Reduction ratio, 1 to 1.52 of crank shaft.
Ignition	2 special dual magnetos; anticlockwise rotation.
Oil consumption	0.02 pint, approximately, per British horsepower hour at full load.
Fuel consumption	0.51 pint, approximately, per British horsepower hour, full load.
Self-starter	Napier patent air petrol system.
Weight of engine	850 pounds, approximately, complete, with propeller boss, carburetors, induction pipes, etc.
Weight of horsepower	1.89 pounds.
Length over all to center of propeller	4 feet 8 inches, approximately.
Width over all	5 feet 6 inches, approximately.
Height over all	5 feet, approximately.

4. ROLLS-ROYCE EAGLE TYPE ENGINES (BRITISH).

1. Rolls-Royce Eagle type engines are 12-cylinder units, with a 4½-inch bore and a 6½-inch stroke. They were rated at 360 horsepower at a normal speed of 1,800 revolutions per minute, and, including the reduction gear which reduced the propeller speed to 1,080 revolutions per minute, weighed 877 pounds. Machine steel forgings fastened to the crank case by four bolts were used for the cylinders. The heads were of spherical shape and the valve ports were integral with the cylinder, the valves being inserted in an inclined position. Two-piece pressed steel water jackets were welded to the cylinders. Aluminum pistons were employed, and the connecting rods were steel forgings machined all over. These rods are of the so-called articulated pin type, where the main rod carries a pin on the big end, on which is pivoted the articulated rod serving the other side of the engine.

2. The crank shaft is of the standard 6-cylinder type and is bored out on pins and journals to carry oil as well as reducing weight by removing material that is not actually needed. This form of crank-shaft construction provides a pipe that supplies oil under pressure to all the working joints of the engine mechanism. It receives its supply under pressure through the main bearings and in turn feeds the lubricant to the connecting rod big end and to the piston rings through pipes in the connecting rod. The lubrication of the cylinder walls is accomplished by the oil which leaks from each end of the crank-shaft bearing and the connecting rod being flung against the walls by the cranks. A geared pump at the rear end of the engine supplies the lubricant under pressure from an external tank that is mounted in such a position that it is cooled by the air draft. The oil which drains into the crank case and is returned to the external tank after straining is taken care of by a different portion of the same pump. Oil does not accumulate in the base chamber and therefore is not subject to heating by conduction from the engine. The crank case is made of two aluminum castings. The upper half is designed for rigidity and the lower half, which is fastened to it by a large number of bolts, provides additional stiffness.

3. The cam shaft, magneto, and other auxiliary drives are located at the rear of the engine. The water and oil pumps are mounted on the accessories drive unit at the rear of the engine. The inlet and exhaust valves are operated through rockers from a cam shaft extending across the top of each row of cylinders. This mechanism

is completely inclosed and is lubricated from the main system. A single centrifugal pump at the rear end of the engine operates the circulating system. The hot water is taken from the uppermost point of the cylinders and conducted to the radiator through two manifolds and enters the jackets at their lower ends through two pipes.

4. The ignition system consists of four 6-cylinder magnetos for each engine, thus giving each cylinder two entirely independent systems. The carburetors, four in number, are provided with means of adjustment to take care of changes in climate and altitude encountered in flight and are designed to feed three cylinders each through an inlet pipe that divides into three branches.

NOTES ON ROLLS-ROYCE MOTOR—"THE EAGLE."

[Compiled from notes of motor mechanics who were stationed in England.]

Type.—12 cylinders "V."
Number of cylinders.—12.
Firing order.—1A, 2B, 5A, 6B, 3A, 1B, 6A, 5B, 2A, 3B, 4A, 4B.
Bore.—4½ inches–114.3 mm.
Stroke.—6½ inches–165.1 mm.
Displacement.—Per cylinder, 103.3 cubic inches; total, 1,240 cubic inches.

Compression ratio.

Eagle series.	Rated power.	Revolutions per minute.	Normal British horsepower.	Compression ratio.
1	225	1,800	254	4.53
2	250	1,800	265	4.53
3	250	1,800	285	4.90
4	250	1,800	285	4.90
5	280	1,800	307	4.90
6	300	1,800	322	4.90
7	300	1,800	322	4.90
8	360	1,800	360	5.30

Normal speed.—Normal crank shaft, 1,800.

Relative speeds.

Crank	1,600
Cam shaft	800
Propeller	1,024
Magneto shaft	2,400
Starting crank	(6 to 1°)
Water pump	2,400
Oil pump shaft	754

Normal horsepower. (*See* data under Compression ratio.)
Guaranteed life at normal speed.—200 hours.

Normal fuel and oil consumption.

Eagle series.	Gas per horsepower hour.	Oil per horsepower hour.
1	0.614	0.023
2	.570	.022
3	.565	.021
4	.565	.021
5	.554	.023
6	.499	.023
7	.499	.023
8	.460	.023

Encombrement.—Overall dimensions:

	Millimeters.
Length	1,105
Width	810
Height	903

Weight dry in pounds.—Eagle series:

1	900
2	907
3	907
4	905
5	910
6	960
7	960
8	947

Valving and valve gear.—Cam-shaft position, overhead; Three cam-shaft bearings.

Timing:

Inlet opens	10° past top D. C.
Inlet closes	54° past bottom D. C.
Exhaust opens	58° before bottom D. C.
Exhaust closes	10° past top D. C.
Full advance ignition	35°.
Full retard ignition	12°.
Tappet clearance	0.005 inch with motor warm.

Valve spring.—Two springs are used on each valve and are wound in opposite directions.

Tension closed, 35.5 pounds.

Tension open, 49.5 pounds.

Valves:

1 inlet diameter, 50.8; lift, 9.5, 11.17, 12.27.

1 exhaust diameter, 50.8; lift, 9.5, 11.17, 12.27.

Piston.—Piston is of aluminum of the zepher type with wrist pin close to bottom in order to cool wrist pin.

Weight of old type, 2 pounds 2 ounces.

Weight of new type, 2 pounds 12 ounces.

Three rings and one scraper ring gap, 0.015.

Connecting rods:

Articulated type.
Firth-chrome vanadium steel.
Articulated rods always lead.
Cylinders are at 60° angle; included angle rod is 65°.

Wrist pins.—Casehardened nickel steel secured by flanges on one and lock pin on the other.

Crank shaft:

Chrome-nickel steel.
Hollow journals.
Seven main bearings.
Epicyclic reduction gearing is used.

Cylinders.—Steel. Turned from solid and jacket welded on.

Cooling system:

Centrifugal pump—delivery of water, 24 gallons per minute.
Capacity recommended, 11 gallons.
Temperature control in Avion is by shutters over radiator.
Normal water outlet temperature is 75° to 80° C. Water should be changed after 30 hours running.

Oil system.—Oil is drawn from filter in sump. Pump is of rotary gear type and has two pressure valves—one for a pressure of 30 to 40 pounds and the other 2 to 3 pounds. The high-pressure supply leads from the pump to the main oil header. This header feeds main bearing and rods, big and small ends. The low-pressure oil feeds timing gears, reduction gears, and main thrust bearings. Jets of low-pressure oil fall on crank pins. Cam shafts are hollow and low-pressure oil is lead into them, which lubricates, through holes, the cam-shaft bearings. The surplus oil which collects in cam-shaft housing lubricates cams and rockers and the air pump and revolution counter drive. This oil returns to the sump through vertical drive-shaft housings. Oil collected at the other end of cam-shaft housing is drained to sump through pipes which lead into the crank case.

Magneto drives, valve stems, and springs should be oiled occasionally by hand. Oiling system should be cleaned after every 30 hours' running.

Air-pressure pump.—This pump is placed on front end of one cam shaft and is adjusted to supply air pressure not to exceed 3 pounds per square inch. It is of plunger type.

Noureturn valves are placed in head of pump, one feeding pressure pipe and one the relief valve. Relief valve is controlled by a screw on top of the valve chamber.

The pressure from pump is led to the gasoline tank, which has an independent relief valve and a pressure gauge.

Pump is lubricated by oil from cam-shaft housing.

Carburetion.—Two carburetors are used, each supplying a group of six cylinders. Carburetors are of Claudel-Hobson make.

Intake manifolds are water jacketed.

Jets are marked according to the amount of gasoline which will flow through them per minute under a given head of 55 cm.; 650 cc. jets are used in this engine.

Clearances.—Piston-ring gaps:

	Inches.
190 horsepower	0.012
250 horsepower	.015
275 horsepower	.015
Top ring in groove	.003
Bottom ring in groove	.002
Valve stem clearance	.004

Diameter on valve seats—2 inches on 250 horsepower; 1.75 inches on 190 horsepower.

Side clearance on big end rod bearings 0.025 inch, excepting reduction end adjacent bearing, which has only 0.0015 inch on each side to keep shaft from floating.

Spring drive.—This is interposed between the crank shaft and reduction gear to prevent shock or gearing and to damp out torsional vibrations of crank shaft. Drive is taken through eight springs set circumferentially around a spider and attached to the internal gear of the planetary reduction system. A friction device of the disk-clutch type with fiber washers is used in connection with the spring drive to dampen out vibrations.

Reduction gears.—Epicycloidal or planetary type. Reduction ratio, 25 to 16; engine speed, 1,600 for propeller speed of 1,024 revolutions per minute. Ratio same for all motors. Internal gear carried on crank shaft and driven through spring drive. Satellite gears are carried by three pins on a spider which carries the propeller hub. Sun gear is stationary and fixed to the crank case.

Gears are as follows:

Internal tooth gear, 120 T.; meshing with 3 satellite gears, 45 T.; integral with 3 satellite gears, 30 T.; meshing with 1 sun gear, 45 T., which is stationary.

$$R=(45/30\times45/120)-1=25/16$$

Assembly forms unit, which may be removed as a whole from the crank-shaft joint between gear housing and crank case.

The Eagle.—The "Eagle" has a bore of $4\frac{1}{2}$ inches, a stroke of $6\frac{1}{2}$ inches, weighs 823 pounds, 1,800 revolutions per minute; British horsepower at normal revolutions per minute, 350.

The Falcon.—The "Falcon" has a bore of 4 inches, a stroke of $5\frac{3}{4}$ inches, weighs 650 pounds, 2,000 revolutions per minute; British horse power at normal revolution per minute, 270.

5. THE SALMSON ENGINE—TYPE 9Zm (FRENCH).

INTRODUCTION.

Our engine, type 9Zm, is the result of methodical work, with the object of meeting the most exacting requirements of military aviation.

Experience with our preceding engines and the use of pistons made of an alloy of aluminum having shown us the possibility of gaining in power and lightness, new investigations were immediately begun.

Having made various types of engines, with parts calculated with the same coefficients of safety, we have returned, after testing, to our model with nine radial cylinders.

This arrangement, which requires only a short crank case and a single crank arm on the crank shaft, is of great advantage to the engine, especially from the point of view of lightness, solidity, balancing, and centering on airplanes.

We have fixed the dimensions of 125 bore and a long stroke of 170 mm.

The connecting rods have been assembled on a master rod. The great length of the connecting rods has facilitated this arrangement without disturbing the cycles, and a well-regulated compensation system gives a good equilibrium.

The speed to which we have thus far been limited permits the coupling of the propeller directly to the engine shaft.

Our valve controls by outside rods and levers are simple, easy to regulate, and easy to watch.

The forced oiling, by pump and visible flow, is much simplified on account of the single crank arm. Its working is only of the surest.

The ignition with two spark plugs per cylinder and two independent magnetos has naturally been retained.

We have retained the water system with centrifugal pump, a method we have always advocated and which is now favored by most constructors.

Fortunate arrangements have enabled us to make the 9Zm with high compression, with no more risk to the valves nor to the spark plugs, and this engine is powerful even at high altitudes.

Moreover, devoting our entire attention to the airplane industry, we have been able to supply our engine with all the improvements indicated by a long and comprehensive experience.

TECHNICAL DESCRIPTION.

Engine.

The engine has nine radial cylinders, located in a plane perpendicular to the axis, inclosed in a two-piece crank case.

The crank shaft is held in the crank case by a thrust bearing on each side and a double thrust collar in the rear.

In front of the crank case is the distribution case whence proceed all valve controls which go above the cylinders. It is through the cover of this case that, by a new thrust bearing, the propeller shaft passes.

Behind the crank case is bolted the support of the pumps and magnetos, about which are grouped the water pump, oil pump, and both magnetos.

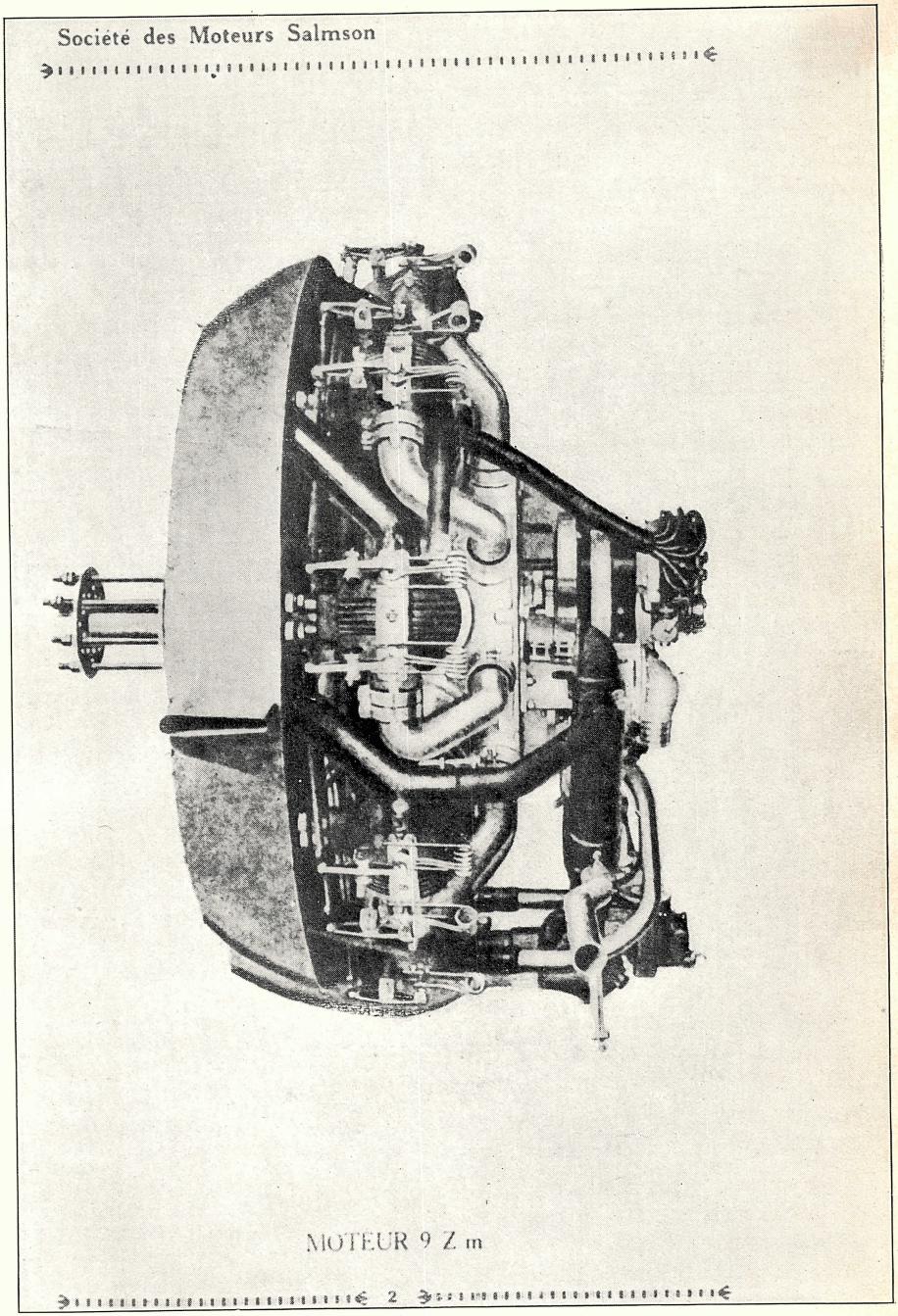


FIG. 1.—THE SALMSON ENGINE, TYPE 9ZM.

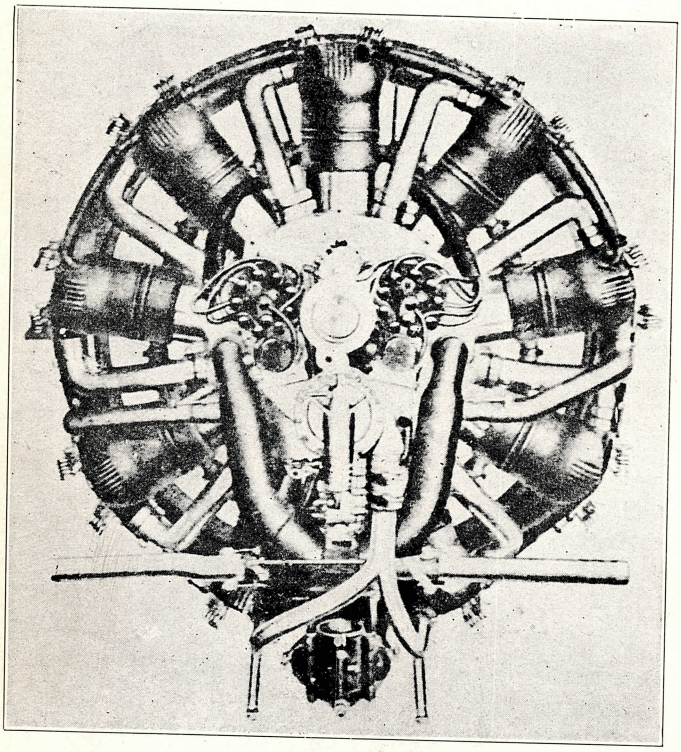


FIG. 2.—THE SALMSON ENGINE.

Viewed from pilot's seat.

The carburetor is under the pumps. It is connected by two heating pipes to the intake manifold coming from the foundry with the rear crank case. From the intake manifold nine intake pipes go to the intake valves.

Nine exhaust pipes conduct the burnt gases from the corresponding valves to the exhaust manifold usually arranged in a crown in front of the cylinders.

The engine is attached by a casing and by lugs on the rear crank case.

Crank Case.

This is made of aluminium alloy and consists of two parts fitting over the plane of the connecting rods. Although not having to support appreciably more stress than the crank case of a single cylinder, it is strongly ribbed and has good guides for the casing of the cylinders. The thrust bearing supports are strengthened by pieces of harder metal. The front part carries the centering of distribution case, the oil intake of the latter, and the lower pocket of oil recovery.

The rear part has inside arrangements for holding the double thrust collar and its lubrication system. On the outside are the centering and the lugs for attaching the cockpit. The manifold came from the foundry in this piece.

Cylinders.

These are made of steel, with water jacket of soldered sheet steel. In the compression chamber studied of the best form there open valves of large diameter with well-cooled guides.

The sparks, which also issue in the explosion chamber, are controlled in such a way as to avoid projections of oil and heating of the spark plugs.

The valve springs, resting on the outside cover, are very visible, as also the control levers of these valves.

These cylinders, inclosed in the crank case, are held in it by a wide flange and tightened by a ring.

Pistons.

These are cast from an especial aluminium alloy that has given the best results in regard to lightness, solidity, and friction. The outer form of the bottom is combined with that of the explosion chamber of the engine. The inside ribs are less in number, but stronger in order to avoid all deformations.

Five soft cast rings assure tightness of cylinder. The oscillation of small end of connecting rod takes place on the wrist pins of pistons, without risk of ovalization from expansion of axis.

Connecting Rods.

These are all of selected steel, suitably tempered. They are very long in order to lessen the amplitude of oscillation of the bearings and consequently their wear. The principal connecting rod turns only on the sleeve of the crank shaft. It carries, in a ring between the ball races of the bearings, all the pins of the heads of the auxiliary connecting rods. Its cross section is in the form of a girder, while that of the auxiliaries is a hollow ring.

Crank Shaft.

This is of nickel steel and has only one elbow. The crank pin forms a single piece with the front part which carries the propeller boss. The rear part is assembled with the crank on a polished cone, bolted and secured by the screw of the crank pin.

The shaft is of large diameter, but central hollows have been bored in order to lighten it.

Opposite to the crank are counterpoises, perfectly tared and verified for each engine.

The oil conduit, which empties into the center of the crank pin, communicates with the outside through the rear shaft.

Bearings.

All the principal engine bearings are ball bearings of the best makes. These bearings, though heavier than the soft bushings, have been chosen for their safety in regard to oiling, for the ball bearings require less oil, are less sensitive to the quality of the lubricant, and can even run for a short time without oiling.

The connecting rod bearings are also ball bearings, but caged in a special manner and tested separately under double load.

The thrust bearing, lodged in the rear crank case, is a double bearing working equally well in pushing and pulling. A central cross brace holds it securely in place and provides for the lubrication of the bearings.

Distribution.

Intake and exhaust valves are located in the cylinder heads.

The valve-control levers, mounted in the yoke attached to the cylinders, receive, through rods of adjustable length, the control of the distribution cams.

All the distribution is done by a six-boss cam mounted on front shaft turning in same direction as engine, but only one-fourth as fast.

Each boss works successively the exhaust and intake valves of the same cylinder. Two opposite bosses on the same circumference of cam suffice to control three cylinders.

Rotation of cam is effected by a gear wheel on engine shaft and a set of intermediate pinions.

The lift of the bosses is transmitted to the valve stems by means of cam followers and guided push rods.

This group is inclosed in the aluminium distribution box attached to front of crank case.

The cam having been accurately made on a scale plate, it suffices to adjust the first boss on cylinder No. 1, in order to have whole distribution perfectly adjusted.

Lubrication.

This is accomplished by a forced circulation of oil, obtained by means of a piston pump located back of engine below water pump. This pump has two pistons; one serves to pump the oil into the crank shaft; the other recovers the excess of oil that has fallen into the depression of the crank case and returns it to the reservoir.

The pump movement works in the oil and is inclosed in a tight casing in communication with the reservoir and in which the first piston can draw in through a wide opening in order to avoid all loss of priming.

An outside pinion receives the control of the rear shaft of engine through the gear of the water pump. On the shaft of this pinion, on the inside, is an endless screw reducing the speed on a helical gear bearing the crank pin of both pistons. There is no connecting rod. The pistons in their motion cause body of pump to oscillate, and this motion uncovers at the proper time the orifices of suction and of delivery. There are therefore no flap valves.

The oil delivered to the engine enters the rear end of shaft through an oil hole, follows the center of the shaft, the center of the crank web, and comes out at a single point in the middle of the crank pin, projected by centrifugal force. The central bore of the connecting rod bushing presents successively to this jet smooth surfaces and holes.

The smooth surfaces distribute the oil to the connecting rod bearings, which, once saturated, project it into the crank case.

The holes lubricate directly the axes of the connecting rods which the oil covers and then passes to the axes of the pistons.

The excess of oil in the pistons, like that projected through the crank pin, is collected on the front side of crank case for the bearing and distribution casing; on the rear side of crank case, for the bearing and both faces of thrust collar.

Since the pump delivers much more than the necessary oil, the large excess falls into the depression at the bottom of the crank case from which the recovery piston sucks it up.

Water Circulation.

As already mentioned, the cylinders are cooled by water. A centrifugal pump, located at the rear of the engine, is controlled by the engine shaft by means of straight gears.

The radiator water enters, through the cover, the center of the revolving part. It is delivered to the pump by a tube increasing in size up to the delivery nozzle. A guide divides the water in the two lower cylinders 1 and 9, causing it to go to the right and left in two streams.

The water circulates between the cylinders through pipes connected by elastic joints and in such a manner that no pocket of steam can form. The two currents unite at the top on cylinder 5, whence the water is conducted to the radiator. A filter must be connected with this pipe to catch limestone deposits.

Tachometer.

The reduction gearing of the tachometer is located at the rear end of the shaft, on the cover of the water pump. It is controlled by a small moving shaft. The reduction is in the ratio 2 to 1, adopted for tachometers, and the projecting sleeve is ready to receive the usual flexible connection.

Ignition.

The double ignition is assured by two Salmson magnetos working separately. They are of the G.G.9 type, with stationary armature and revolving sleeve. These magnetos give four sparks per revolution of sleeve, allowing them a speed half as large as that of magnetos with revolving armature which give only two sparks per revolution of armature.

Each cylinder has two spark plugs. Each magneto supplies a group of nine spark plugs and is itself capable of running the engine.

Both magnetos, symmetrically located at the rear of the crank case on the pump supports, are controlled by straight gearing. These revolve at nine-eighths of the speed of the engine.

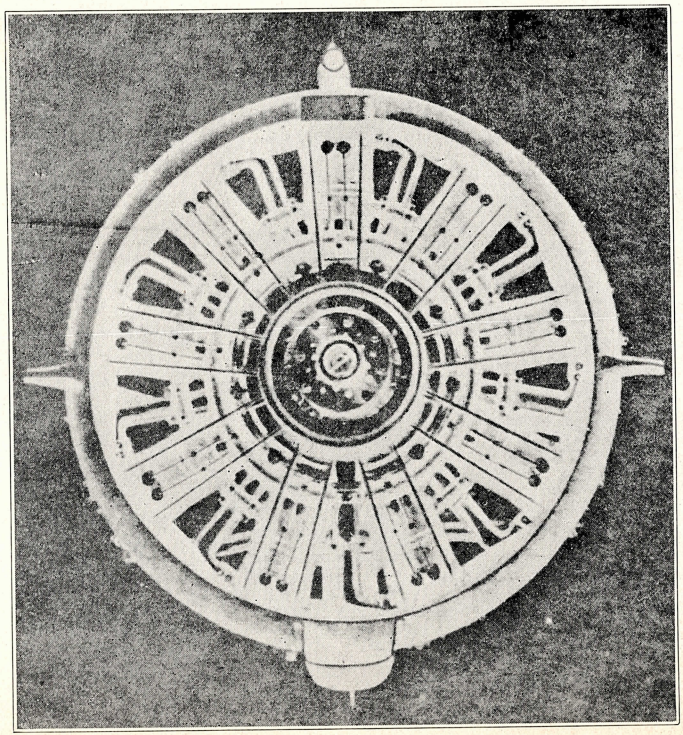


FIG. 3.—ENGINE WITHOUT RADIATOR.

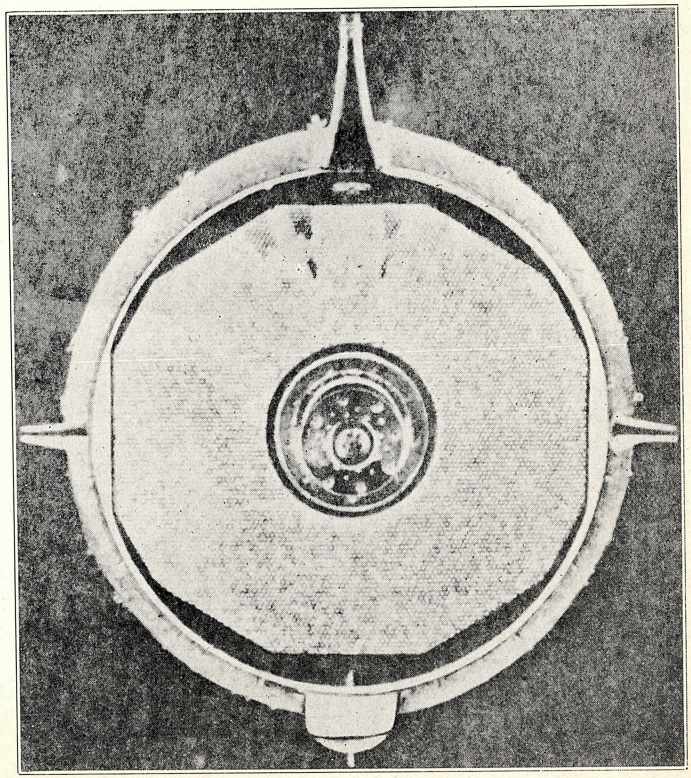


FIG. 4.—ENGINE WITH RADIATOR.

In magnetos with sleeves, the rotation of the sleeves, about the stationary armature bearing the windage and situated in the magnetic field of the permanent magnets, produces four times per revolution, in this armature, sudden variations in the intensity of the field, and thereby engenders a current in the primary coil. The ends of this coil formed of several turns of large wire are connected to each other by means of the platinized screws of the interrupter and of the ground wire closing the circuit. At the instant this current attains its maximum value the cam suddenly raises the interrupter, thereby breaking the circuit. At this instant there is produced an extra current which increases the value of the first and induces in the secondary coil, consisting of a large number of turns of small wire, a high-tension current capable of giving a very hot spark between the electrodes of a spark plug.

The condenser, placed in shunt with the terminals of the interrupter, is charged at the instant of opening the primary circuit, reinforces the current, and suppresses the break spark which would be produced between the platinized screws and which might injure them.

The high-tension secondary current is conducted to the rotary brush during its rotation, which takes place at four-ninths of the speed of the magneto shaft. The brush comes successively in contact with the different plugs embedded in the body of the distributor in order to transmit the current to them. These plugs are each connected to one of the terminals of the periphery of the distributor and, by the aid of conductors, to the spark plugs of the engine.

In order to allow the use of starting magnetos to facilitate starting the engine, the rotary brush of the ignition distributor has a conducting ring and a brush in the rear of the rotary motion with relation to the brush of regular flying magneto in such a manner that the ignition is delayed and always occurs in a cylinder that has passed the compression period.

The current of the starting magneto is brought by a well-insulated cable to the terminal of the distributor designed for this purpose. The brush causes the ignition in the proper cylinder to insure the first motive impulses. The running magnetos then insure the normal working of the engine.

From the preceding it is easy to see that it is absolutely necessary to adjust accurately the sleeve of the magneto with reference to the crank shaft of the engine, since the ignition point on the engine comes at a precise phase of the stroke while on the magneto it takes place

at a certain well-defined position of the sleeve. Furthermore, the operation of the magneto by the engine must take place without possible displacement.

Since the magnetos can be dismantled and repaired only by specialists, we will not go into details.

Carburetor "Zenith."

This is type 55 D. C. with compensation. It consists of two bodies side by side fed by a single float chamber. All the other parts (jets, compensators, low-speed adjusters) are in duplicate.

Operation.

Its normal operation is the same as that of the automobile type. Since upper part of float chamber is in communication with the air intake, the atmospheric pressure between these two points is balanced.

The effect of the suction in the mixing cone empties the shafts of the compensator and jet. The *compensator* gives a constant quantity of gas per unit of time, since it delivers at atmospheric pressure under the constant pressure of the float. The delivery of gasoline through the jet, being strongly influenced by the suction, is proportional to the quantity of air passing through the mixer.

As a result of the operation of these two different laws of flow, the total output is such that the carburetion is perfect for all speeds for the various positions of the butterfly valve.

At low speed the butterfly valve is almost closed and the jets no longer flow. The feeding of the engine is assured by a rich emission of gasoline emptying against the edge of the butterfly valve from the low-speed jet.

The low-speed pipe takes the gasoline from the bottom of the compensator shafts and the air from above through an adjustable annular orifice. By screwing in this jet, the mixture is enriched. By unscrewing it, it is impoverished.

The gasoline is delivered into a filter of large surface. The float is spherical, so that the level does not change in the float chamber for inclinations up to 45°.

The jets being placed very near and on either side of the float chamber, the carburetion is not affected by the different positions of the machine.

In cleaning, never remove the tubular part within the mixer. Be careful to hold nut of filter base with a wrench, while removing gasoline intake connection.

Altitude Corrector.

The carburetor has an altitude corrector whose rôle is very important. It consists of a pipe with a cock opening in the same direction as the butterfly valve and allowing the air to enter the passage from the jets to the central tubular part.

The proportion of gasoline, or richness of the mixture, is diminished as the cock is opened wider.

The necessity, due to the rarefaction of the air, of reducing the proportion of gasoline, as the airplane ascends, may thus be satisfied at each altitude by moving the corrector.

The best position corresponds to the highest power of the engine. Starting with a very rich carburetion, the proportion of gasoline is gradually diminished by opening the corrector. Then, observing the tachometer, the speed will be seen to increase, reach a maximum, and begin to drop. The lever is then brought back a few degrees. By this method the corrector may be suitably adjusted for economizing gasoline.

Adjustment of Carburetor.

Carburetor 55 D. C. mounted on engine 9Zm is normally adjusted as follows:

Mixers	42
Jets	260
Compensators	180

There is no occasion to change these adjustments, excepting when the altimetric corrector is not sensitive enough, which would cause too small jets.

ADJUSTMENTS.

Adjustment of Distribution.

The first adjustment to be made is that of the valve controls. Operating by the cylinder, turn engine in order to make sure that the push pins of the corresponding cam followers are not attacked by the bosses of the cam.

Loosening nut side of levers, adjust control rods in such a manner as to leave an average play, when cold, of 0.2 mm. between end of valve stem and the lever.

Then tighten nut while holding stem. This is done successively for all nine pistons.

Since the control rods are long, the adjustment must be good, because it can not get out of adjustment with the inside gear.

Verification of the adjustment is facilitated by the outside marks on the shaft, distribution cover, and propeller boss.

In order to make this adjustment in mounting the engine, with the cover of the distribution box removed, cylinder No. 1 is operated on. The piston of this cylinder is brought to the dead point, by the reference marks, before removing cover, or with an indicator at the bottom of the stroke through a spark-plug hole. Then, while turning cam alone, one of the bosses is placed between the two rockers, in position corresponding to end of exhaust, beginning of intake, and dead center. At this moment, assemble the cam gears, put on control pinion, and key it to shaft while pushing gently on the intake.

Make an immediate verification which should give the following adjustments:

Intake.

Opening.—Upper dead center or several degrees advanced.
Closing.—55° past lower dead center.

Exhaust.

Opening.—65° before lower dead center.
Closing.—Upper dead center.

For the other cylinders, the divisions being exact, the adjustments are automatic.

The point of closing the intake valve and opening the exhaust valve are the ones which must be the most accurately adjusted. The intake opening and the exhaust closing may overlap slightly at the upper dead center.

Adjustment of Ignition Magneto.

In order to make this adjustment, turn engine gently by hand until piston of cylinder No. 1 is near the end of its compression stroke, about 35° before upper dead center. This point is marked on the distribution cover.

Uncovering the interrupter of the primary coil of the magneto and removing the cover of the ignition distributor, turn pinion by hand, in the running direction, until brush of distributor is opposite contact of wire No. 1 and at precise point of break of the primary coil.

A cigarette paper held between the two platinum contacts must just be able to be withdrawn without tearing when the make and break begins.

In this position the magneto is geared with the pinion of the engine at same time as placed on its support. The ignition point is immediately verified in order to see whether the gears have been properly adjusted.

The wires are arranged on the distributor in the order of ignition 1, 3, 5, 7, 9, 2, 4, 6, 8. These wires are all marked at both ends with the number of the corresponding cylinder engraved on a small brass ring.

After adjustment of cylinder No. 1, all the other cylinders are automatically adjusted as soon as the wires are in place.

DISMANTLING OF ENGINE.

INSPECTION, VALVE GRINDING.

Dismantling.

Without entering into the details of this operation, we will give the general order.

Before removing engine from its support, disconnect it from the carburetor, the heaters, the rear support complete with the pumps and magnetos. Remove oil plug from shaft. Loosen rear control pinions, remove the small key and washer of rear adjustment.

Lay engine flat, with rear part of crank case resting on a wooden support. If radiator is in front of engine, remove it with its attachments.

Remove exhaust manifold, intake pipes, control rods, push pins, wire conduit. Loosen and remove propeller boss and key.

Remove cover of distribution box, cross brace, adjustment washer. In distribution box, remove intermediate canvas, with the small wheel, control pinion, and key, and cause cam to turn in order to separate rockers.

Unscrew nuts of distribution box. Withdraw cam, taking care to leave its lower bearing in place. Remove distribution box.

Loosen and draw back cylinder collars and loosen rubber collars.

Unbolt crank case and, removing all bolts except the one under the filter, remove front part of crank case.

Remove shaft, connecting rods, and cylinders, attaching to copper jet the roller in the rear bearing. This roller will then be driven in with the cross brace of the thrust block in order to make the latter sufficiently visible. Remove cylinders.

It is then possible to inspect the engine in all its parts, and it is better not to dismantle it further. It may always be done in the following manner: Remove pistons after having unbolted and driven out the pins. Dismount rear shaft while driving out front shaft with a steel punch after having removed screw of crank pin and wedges.

Assort the connecting rods and their bearings. Drive out the pins of the auxiliary connecting rods.

Assembling.

This is done in the reverse order from dismantling, while abundantly lubricating the interior parts with all possible care and cleanliness.

The wire conduit (collecteur de fils), push pins, control rods will naturally be mounted as soon as the cam is taken down for adjustment.

Valve Grinding.

After the cylinders have been separated from the engine, the valves are removed. For this purpose, remove the safety wire, the semicircular wedges, the cups, and springs by bearing on the latter with jointed pliers. The valve comes into inside of cylinder.

The grinding is done with very fine emery powder mixed with oil. The oscillation is effected from the outside by means of a special wrench. A well-ground valve and seat must show surfaces of a uniform dull gray color.

After grinding, valves and cylinders must be carefully washed in order to avoid injury of the rubbing surfaces from the emery.

PREPARING AND STARTING ENGINE.

Fill oil and gasoline tanks, taking care to filter liquids, the latter through a chamois skin. Open oil, fill crank case and oil pump.

Put oil in oil holes of valve-control levers, on valve stems and springs, and on the rear gearings. For 10 or 15 hours' running, place a drop of oil in the oil holes of the magnetos. Inject oil into the oil hole of ball bearings of distribution cover. Inject oil into oil tube of machine-gun control.

Fill oil cup of water pump. If it has frozen and even the water has been emptied on stopping, there may remain a little ice in the water pump. This is thawed with warm water, in order to avoid breaking the rotating part.

The same precaution must be taken for the oil. Pour warm oil into tank, and through the air outlet cock inject some into the pump case.

See that spark plugs are in good condition. Their electrodes must be 0.3 to 0.4 mm. apart.

Turn engine gently by hand. It must be quite free with spark plugs removed. Otherwise, inject a little kerosene into the cylinders.

See that valves do not bind in their guides and that the springs work energetically.

See that radiator and cylinder jackets are filled with water.

Supply gasoline to the carburetor. It is well to inject a little gasoline into the gas manifold, not exceeding 100 cc.

Adjust carburetor at low speed.

Turn propeller vigorously by hand, with contacts closed, in order to charge the cylinders.

Start the starting magneto and release both running magnetos as soon as the first explosions are heard.

First turn to the speed of about 500 revolutions per minute.

See that the oil and water circulations are well established.

Slowly open throttle up to normal speed of engine.

By cutting out the two magnetos separately the speeds obtained should be practically the same.

Adjust the altitude corrector on its first notches in endeavoring to obtain on the ground the maximum speed, which corresponds at the same time to the best carburetion for the gasoline used and the atmospheric conditions of the moment. Carefully reserve, on the ground, the last notches of the corrector in order to have all the latitude of adjustment possible for the higher altitudes.

This operation of standardizing at a fixed point, with wide open throttles, should not last more than a minute.

Starting with Starting Carburetor.

In order to start with a small starting carburetor without gasoline pump, proceed as follows:

Completely close throttle.

Have propeller vigorously turned while opening the cock of starting carburetor. Release this cock, which the spring will close, and stop turning.

Open throttle a few notches on the sector.

Start the starting magneto. At the first explosions, work the switches of the magnetos as already indicated.

MANAGEMENT OF ENGINE.

The pilot is rcommended:

To pull gently on throttle.

To adjust on ground and every 500 meters after 1,000 m. the handle of the altitude corrector as already explained.

In summer, to adjust the heating control of the carburetors; in winter, to open heater wide.

Every half hour to take a half turn with the key of the lubricator of the water pump.

To verify oil flow through inspection opening.

To avoid increasing engine speed to over 1,500 revolutions per minute below 2,000 m. of altitude.

DIFFICULTIES AND THEIR REMEDIES.

Difficulty in Starting.

Difficulties that may be encountered in starting proceed from three causes: Defective ignition, poor carburetion, or lack of tightness of engine.

In the case of starting with the propeller, the ignition current is produced by the starting magneto. It is therefore easy on turning starting magneto independently of the engine to see whether it gives sparks.

If the engine gives any sparks while starting magneto is being run, it may be concluded that the defect exists in the magneto or magnetos. The most frequent trouble is the failure of primary interrupter from the swelling of the fiber washer or the platinized screws becoming covered with oil. This results in the magnetos refusing to spark at first. This part must therefore be inspected to see that it is clean and works freely.

In case the engine has been for some time in a damp place, there is deposited on the porcelain of the spark plugs and on the parts of the ignition distributors water vapor which has the effect of greatly diminishing the heat of the spark. This may render the starting of the engine very difficult.

We recommend, before starting, to clean the spark plugs with gasoline, to dry them properly, and to wipe carefully all the high-tension parts of the magneto, distributors, and binding posts.

Difficulties arising from defective carburetion at the start are not generally attributable to the carburetor, but to the supply of gasoline delivered in the intake manifold.

In order to insure the starting of the engine, it is necessary to deliver a volume of about 100 cc. We show in the catalogue that two volumes must be delivered from the pump. This quantity of gasoline must not be increased on account of danger of filling engine with gasoline and not being able to start it. In case of doubt in regard to working of gasoline pump, it is necessary to unscrew connection on engine case and see that there is plenty of gasoline in this vicinity. This injection of gasoline is never of any use if the start is made with a small special carburetor.

Too large a play of the intake valve stems in their guides, allowing entrance of a little air, may interfere with starting. A light oiling of the stems is generally sufficient to obviate difficulty.

Lack of Tightness.

Tightness of the engine is one of the essential conditions of its good working. It is necessary to verify it frequently by removing all the spark plugs, excepting in the cylinder to be tested. Then, by turning propeller by hand, the compression is easily felt. In case of lack of tightness of an intake or exhaust valve, the engine must not be kept running in this condition.

Misfire.

1. *Always in same cylinder.*—In this case the fault may reside in the spark plug, wire connecting spark plug to magneto, failure of a valve to close, lack of tension of a spring, entry of air into intake tube or cylinder, or broken cylinder rings.

Defects in valves, springs, or cylinder rings are confirmed by testing tightness, as already indicated. For spark plugs, they may be short circuited by the presence of a foreign liquid—oil, water, gasoline—or be damaged as a consequence of the porcelain being broken or a considerable accumulation of carbon from the working of the engine with an excess of gasoline or with a gasoline of poor quality.

2. *Several cylinders.*—After it has been ascertained that the misfires take place in several cylinders in a regular order, it may be inferred that the magnetos are at fault, in which case they must be exchanged.

Poor Carburetion.

The difficulties from this source may be manifested in several ways.

1. *Lack of gasoline.*—The carburetor is adjusted with a lack of gasoline for running at high power. At this point, confirm the following fact: That, on starting, the engine runs properly up to 700, 900, 1,200 revolutions per minute and that it is impossible to enlarge opening of butterfly valve without back fire. This confirmation proves either that the jet is too small or obstructed or that the gasoline is delivered too slowly on account of defective installation, or that some foreign substance obstructs the pipe, or that the needle valve is wedged, or that the altitude corrector is too wide open.

It may be further ascertained whether the engine starts with the gasoline injected into the manifold and whether it stops after a few turns. This defect indicates that the low-speed opening is obstructed or too small.

The same defect exists if the engine does not turn at a speed lower than 800 revolutions per minute, for example. The section of the compensating jet being suitable, the engine should rotate uniformly at 350 revolutions per minute.

2. *Excess of gasoline.*—This may be confirmed by the fact that the engine does not rotate at its regular speed, that it gives out black smoke, or that it overheats.

The method of verification is to inspect the spark plugs. In case of an excess of gasoline there will be an abundant deposit of carbon. At low speed, excess of gasoline is manifested by very large smoky red flames, which come out of the exhaust pipe. Adjust either the main jet or the compensating jet.

3. *Heating.*—A third disturbance of the carburetion may come from the condensation, due to a lack of heating or the use of poor gasoline not sufficiently volatile. This manifestation of the defect is in the misfires of certain cylinders accompanied by smoke.

4. *Altitude corrector.*—This allows a rapid investigation of the carburetion. If for an established speed the speed increases on opening it a little, there is too much gasoline. On the other hand, if the speed diminishes, there is too little.

The corrector may therefore allow all degrees of carburetion, even poor, and, in altitude, from the fouling excess of gasoline to excess of air with back fire, if the throttle is not at the right notch for the height at which the airplane is flying.

Remember that good carburetion corresponds to the maximum revolutions per minute for a given supply of gasoline.

Excess of gasoline warms water of circulation a little. Excess of air warms it considerably.

Miscellaneous.

The further troubles that may occur from faults in the mechanism itself usually come from the valves, distribution parts which bind and do not work free enough, or from poor adjustment of valve controls, which prevents an exhaust or intake valve from closing.

There may also be troubles due to excess of oil. The oil pump for emptying the crank case may fail to work on account of leakage of the connections and the presence of obstructions in the intake pipes. It is best to take apart and clean these pipes quite often as also the filter which receives the oil from the crank case.

Gasoline.

We recommend the use of gasoline of density of 0.69 to 0.715. There may be troubles whose cause does not appear in the mechanism itself, but come only from excessive density of the gasoline.

Oil.

We have obtained the best results with castor oil of good quality.

Water.

The cooling water which circulates in the cylinders and radiators must be free from acid and limestone. A filter must be placed in the circulation at the outlet of the cylinders. This must be cleaned occasionally.

In very cold weather, notwithstanding all other precautions, it is wise to render the water noncongealable by the addition of considerable glycerine or alcohol.

6. SIEMENS-HALSKE ROTARY ENGINE (GERMAN).

This 200 horsepower 11-cylinder motor is a development of the previous 9-cylinder engine of 110 horsepower. It differs from that engine in that, whereas in the smaller motor the crankshaft was stationary and the cylinders revolved, in the new engine the crank shaft revolves in one direction and the cylinders in the opposite direction. The cylinders revolve at the rate of 900 revolutions per minute in one direction, and the crank shaft makes 900 revolutions per minute in the opposite direction. This is equivalent to an engine speed of 1,800 revolutions per minute, while the speed of the air-screw is only 900 revolutions per minute.

The arrangement of having the two masses rotating in opposite directions is attended by the following special advantages: The low speed of the air screw results in a better propeller efficiency, which means a greater useful thrust. On account of the low speed of the cylinders the centrifugal force is smaller, which makes for reliability. The high virtua speed of the engine (by having cylinders and shaft revolving in opposite directions—Editor Flight) results in greater power and lighter engine weight. On account of the low speed of the cylinders, air resistance is decreased, resulting in a better efficiency. By having the masses revolving in opposite directions gyroscopic force is approximately eliminated, which is an advantage for maneuvering. The petrol consumption is far lower than that of any other rotary, and is about the same as that of stationary engines.

The Siemens rotary can be throttled down from 900 to 350 revolutions per minute. The cylinders can be easily removed, and by fitting dual magnetos the reliability is increased. The engine can be started by means of a hand-operated magneto. Both inlet and exhaust valves are mechanically operated, and the motor is overdimensioned, and consequently suitable for work at great altitudes. The normal brake horsepower is 200 horsepower and the maximum power 240 horsepower, for a total engine weight, ready for running,

of 194 kilograms. This gives a weight per horsepower of 0.81 kilograms. If one at the same time bears in mind the low speed of the air screw, resulting in a good efficiency of 68 per cent, or so, the value of the engine will be apparent. (A propeller efficiency of 68 per cent does not impress one particularly.—Editor Flight.) The value of the ratio $\frac{\text{lbs. thrust}}{\text{lbs. weight of engine} + \text{weight of screw}}$, should be very good.

The engine is hung on its three supports in a wrought-iron frame, which is attached by suitable fittings to the four longerons of the fuselage. Later types are improved by making the engine quickly removable with its cowling arrangement. The aluminum cowl round the motor insures proper cooling and prevents the used oil from being thrown out. The oil tank is mounted behind the engine in order to protect it from the cold, and a short distance behind it is mounted the petrol tank, which is arranged for gravity feed. The two tanks are bolted together and may be put into and taken out of the machine as a unit. In later types the oil tank is built with double walls, the space between which is packed with heat-insulating material, so that the oil, even at the greatest altitudes, retains its proper consistency.

7. THE FIAT MOTOR (ITALIAN).

General Principles.

The Fiat aviation engine, A–12, is of the vertical six-cylinder type. It has six cylinders with a bore of 160 mm., stroke of 180 mm.

Horsepower at 1,300 revolutions per minute	225
Horsepower at 1,415 revolutions per minute	245
Horsepower at 1,500 revolutions per minute	255

Cylinders.

The cylinders are independent and made of steel, including the water jacket, which is welded to the cylinder itself. They have four valves in head, which are slightly oblique in respect to the cylinder axis.

Valve Guides.

The valve guides have bronze bushings. Two inlet and outlet unions for cooling water are also welded to the water jacket, and the water is circulated by the means of a centrifugal pump with vertical shaft. Complete draining of the water contained either in the cylinders or the pipe is obtained by opening the water pump petcock.

Timing the Valves.

The valves are operated by overhead cam shaft by means of a lever provided with rollers on the side in touch with the cam, and by air adjustable screw on the side in touch with the valve. The cam shaft is fitted with 12 white metal bearings, which, being very near each other, prevent any bending. The cam-shaft and valve-control levers are inclosed in a tube provided with aluminum and detachable covers which have small lids allowing inspection of the lever rollers in the cams, and permit the introduction of oil for lubrication.

The cam shaft is controlled by the crank shaft by means of two pairs of bevel gears and a vertical shaft. The latter is supported by ball race bearings; also a bevel crown in one piece with the shaft itself. The bevel crown operates the pinions fixed on the small shaft.

Pistons and Connecting Rods.

The pistons are of aluminum alloy. They are fitted with four cast-iron rings at the upper part and one at the lower. The lower ring is a wiper ring. It prevents too much oil passing from between the pistons and the cylinders.

The connecting rods are of chrome nickel steel, small end being fitted with bronze bushings, the big end with white metal bearings. Along the stem of the connecting rod is an oil feed pipe which provides oil for the gudgeon pinions.

The Cam Shaft.

The cam shaft is of chrome nickel steel. It has six cranks and seven pinions. On the front crank pair is a bevel gear for the control of the vertical shaft connected with the cam shaft and for operating the water and oil pumps. In front of this bevel gear there are starting claws in case it is desired to start the engine with the starting handle in place of the propeller. The crank-shaft end in front is in a cone which bears the propeller hub, the thrust of which is supported by a double-thrust ball race.

Upper and Lower Crank Case.

The main bearings are of the split type in the upper crank case. The crank case is of aluminum. The lower crank case, or sump, holds the pipes and pumps as well as the longitudinal shaft drive. The water pump is placed underneath the engine.

Carburetor.

The engine has a double carburetor cast in aluminum, independent float chambers, and vertical throttles. Each carburetor feeds a group of three cylinders. Both carburetors are provided with water jackets for the circulation of hot water coming out of the cylinders. The main jet has a device for regulating the quantity of gasoline. It is used for great heights when the mixture is too rich.

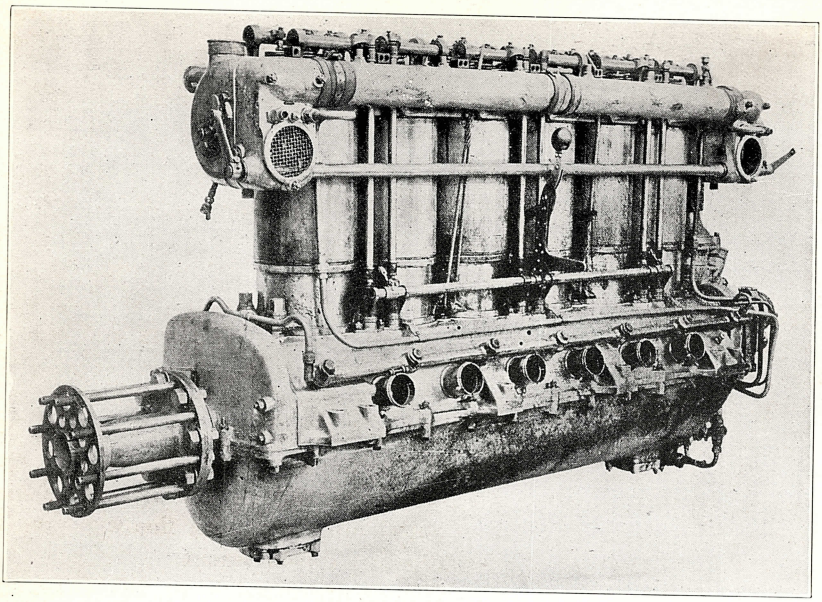
Ignition.

Two high-tension magnetos are placed in front of the engine, producing two sparks per revolution. While the engine performs all its periods in two revolutions, the magneto produces six sparks. Consequently the rotation speed of the magneto is 1.5 times greater than that of the crank shaft. Firing order is 1, 5, 6, 2, 4, the cylinders being numbered from the propeller end. For starting the engine there is also a storage battery which can be inserted in the primary winding of the magneto, i. e., a commutator. This commutator serves to cut out either one of the magnetos, or to stop the engine, or to start it automatically by means of a "trembler" connected with the battery.

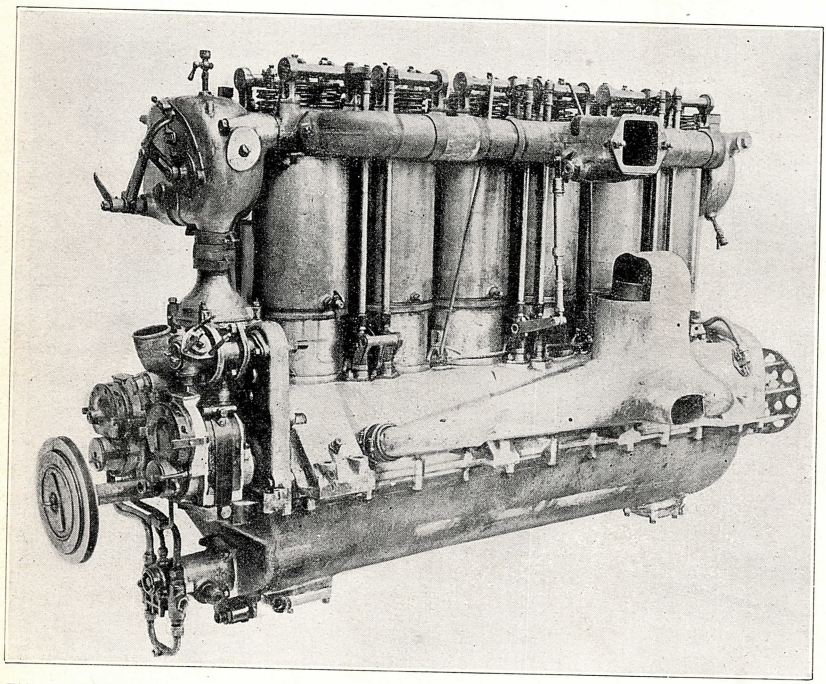
Lubrication.

Lubrication of the crank shaft and of the vertical shaft is effected by oil under pressure which is supplied by a gear pump sucking up the oil from an outside tank. In the sump there are two pumps which suck up the oil which has already passed through the bearings and has gathered in the sump. These pumps work together when the engine is in a horizontal position. When the engine is in an inclined position the oil will gather in one of the lower sump extremities, and then only one pump will work, the other being out of level. The oil goes to a cooler in the sump; passes on to the tank, where it is cooled; and is again sucked up by another pump. The quantity of oil drawn up by the suction pump is greater than that sucked up by the delivery pump, which prevents oil accumulation and an excess of lubrication of the cylinders. The pumps are provided with a filter.

The cam shaft and its controls are lubricated by a special thick oil, which is introduced on top of the engine (by opening the small lids). This lubrication lasts only six hours working. However, even after a short flight, these boxes should be filled. A hand pump is connected with these cam-shaft boxes by means of a special pipe. By this method oil can be supplied to these boxes while in flight.



INDUCTION SIDE VIEW OF MAYBACH ENGINE.



EXHAUST SIDE VIEW OF MAYBACH ENGINE, SHOWING REAR END CARBURETOR AND THROTTLE INDICATOR, WATER PUMP, MAGNETOS, WIRELESS DYNAMO CLUTCH PULLEY, PETROL PUMP, AND GUN GEAR; ALSO CRANK CASE VENTILATOR WHICH HAS BEEN CUT OPEN TO SHOW OIL TRAP.

8. THE 300-HORSEPOWER MAYBACH AERO ENGINE (GERMAN).

General Features.

The 300-horsepower Maybach aero engine presents several unusual and interesting details. The quality of the workmanship of every part, including the exterior finish throughout, is exceptionally good, and the working clearances are carried to very fine limits. Every part, nevertheless, shows the usual German characteristics of strength and reliability, combined with standardization of parts and ease of manufacturing, in preference to the saving of weight.

The general layout of this engine follows the usual German six-cylinder vertical type. The compression ratio is exceptionally high, viz, 5.94: (1) which necessitates the use of very heavy pistons and connecting rods; in these particulars this engine follows the previous Maybach practice, but the adoption of a cast-iron floating bush in the little end bearing is an interesting development.

Four overhead valves per cylinder are fitted, i. e., two inlet and two exhaust. These are operated by rocker levers mounted on roller bearings in brackets fixed to the cylinder heads, and by push rods on each side of the cylinders actuated by separate inlet and exhaust cam shafts.

The cam shafts run in plain bronze bearings in the crank chamber and are splash lubricated.

Little alteration has been made in the design of the massive crank shaft, which runs on plain white-metal lined bearings throughout and is provided with the well-known Maybach type centrifugal pressure lubrication system to the crank pins, thence to the gudgeon pins through small pipes inside the hollow connecting rods.

The three separate and detachable gear oil pumps, which are situated in the bottom of the case chamber, are of new design.

The pump driving shaft at the front end is driven through a ratchet gear on the front scavenger pump, apparently with the object of preventing an air lock in the lubrication system in the event of backfiring.

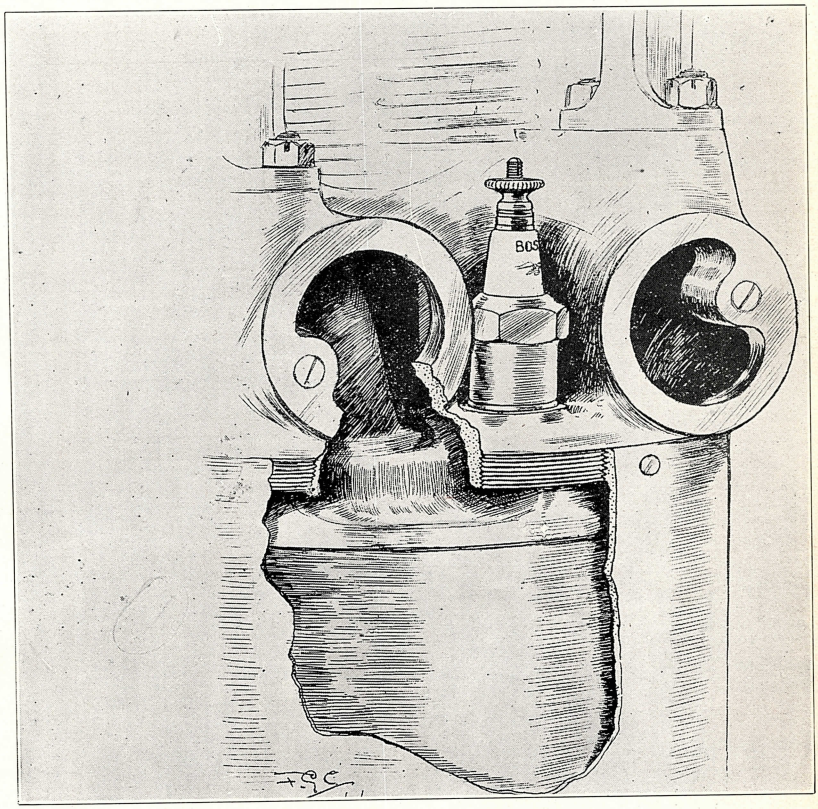
A double-acting oil-sealed petrol pump of unusual design is now fitted. This is driven off an extension of the main pump spindle at the rear end of the base chamber, and works, of course, in conjunction with the two separate carburetors. These are of the well-known Maybach type, and have been only slightly modified. They are attached, as in the Zeppelin engines, to the front and rear cylinder water jackets.

The well-known Maybach induction type starting gear is fitted, but is slightly modified in design.

The whole of the induction system and the oil-condensing crank-case ventilating system is an interesting point in the design of this engine as is also the method of attaching the propeller-hub driving flange on the tapered front end of the crank shaft.

Practically no alteration has been made to the general design of the very simple and efficient type of water pump which delivers directly into the bottom of the rear end carburetor water jacket as in the old Maybach engines. Ignition by two Z. H. 6 type Bosch magnetos, which are driven directly off the rear ends of the cam shafts; the position of the sparking plugs in the cylinder heads is a point of interest.

O



SKETCH OF CYLINDER HEAD IN MAYBACH ENGINE, SHOWING WATER PASSAGES AND CONNECTIONS.

44–1